NDE OF THE ELASTIC PROPERTIES OF FIBER-REINFORCED COMPOSITE MATERIALS

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ABSTRACT

Fiber-reinforced composites are increasingly replacing metallic alloys as structural materials for primary components of fracture critical structures. This trend is the result of the growing understanding of the material behavior and the recognition of composites' desirable properties. Composites are light weight and they have high stiffness, strength, fatigue resistance and damage tolerance. Further, they offer a unique mix of formability and toughness allowing to imbed sensors and actuators to form active/adaptive (i.e. smart) structures.

The determination and assurance of their integrity as well as the material performance require adequate NDE capabilities. These required capabilities include in addition to flaw detection and characterization also the determination of the material properties. The elastic properties of composite materials are important parameters. These properties may vary significantly in different components manufactured under the same specifications and different properties may be associated in a bulk material when compared to laminate form. The variability in the properties requires a careful characterization after manufacturing and at different stages during service. Conventional destructive techniques for the determination of the elastic stiffness constants can be costly and often inaccurate; this is particularly true for the through-the-thickness properties.

An extensive joint JPL/UCLA research program is conducted to develop NDE methodologies for nondestructively measuring composites' elastic properties. Ultrasonic methods using plate wave measurements were developed based on two-transducers pitch-catch arrangements. The specimen is immersed in water, CW/pulsed ultrasonic waves are launched onto the specimen and the response is monitored by a receiver, The amplitude spectra of the reflected wave as a function of frequency is used to determine the dispersion curve of the guided waves generated within the specimen. The dispersion curves are strongly affected by elastic properties as well as the interface and the specimen's boundary conditions. Moreover, the reflected signal in a pulse mode is recorded by the second transducer and it consists of a series of pulses which traveled through the interior of the specimen. Analysis of these reflected signals also provides data that can be inverted to determine the elastic constants.

The CW and pulsed data have been analyzed by means of a theoretical model of wave propagation in the composite laminate. The equations have been inverted to determine the C_{11}, C_{12}, C_{22}, C_{23} and C_{55} elastic constants and the results have shown a sufficient sensitivity to variations in properties to be applicable for practical applications. To enhance the accuracy of the measurements of C_{11} and C_{12}, which are the fiber dominated properties, contact coupling low frequency tests were recently introduced and the results are very promising.

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